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LEVEL PAN CONSTRUCTION FOR DIVERSION AND SPREADING RUNOFF

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The prevalence of extended drought periods, unfavorable distribution of precipitation, high winds and hail are major problems of dryland agriculture in the west central Great Plains. Approximately 60 to 70 percent of the annual precipitation is lost in evaporation and less than 5 percent in runoff. Success or failure in dryland agriculture is dependent on management practices used in conserving the moisture that does occur.

Fallowing is the normal practice of conserving moisture, however, it is not efficient. Various land forming techniques have been developed to improve distribution and storage of precipitation on sloping cropland. The water spreading technique utilizes flood runoff from natural watercourses for spreading on leveled or over inclined pans. Design criteria have been developed for flow and detention type spreader systems (5).

Research on the flow type water spreading system was conducted at Spur, Texas (2). The practice involved the diversion of flood runoff from a watercourse and forcing it to cross and recross 1/2 to 1 percent sloping land through a system of dikes before draining back into the main channel. Results showed that 16 percent more water was stored than fell on the area with 2- to 3-fold increase in grass production. This system is not adaptable for annual crops. In the detention type spreader systems runoff is diverted from a watercourse and spread over a sloping area from a spreader ditch with impoundment of water above the contoured dike. The system allows greater time for infiltration and is adaptable for annual crops. However, in either system stored soil moisture distribution over the spreading area is not uniform.

Spreading flood runoff over leveled areas improved moisture distribution. Burnett and Fisher leveled areas which collected and stored runoff from a contributing area (1). They reported a 59 percent increase in yield of cotton lint from leveled land receiving runoff and 24 percent increase on leveled areas without runoff.

At Bushland, Texas, level benches were constructed on the contour to catch and spread storm runoff from a contributing watershed (3). Annual yields of grain sorghum in the benches averaged 300 pounds more per acre than in a wheat-sorghum-fallow rotation on the contributing watershed over a period of four years.

1/ Contribution from the Northern Plains Branch, Soil and Water Conservation Research Division, ARS-USDA, in cooperation with the Colorado Agricultural Experiment Station.

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A new type of detention spreader system was developed at Akron, Colorado. In this system level pans were constructed in natural drainageways to intercept, spread and store the runoff that normally flowed through them. The experiment was initiated to evaluate the economic feasibility of utilizing watershed runoff on dryland leveled areas for annual cropping. to observe response of different crops to intermittent flooding and study management problems.

This paper reports the results from two leveled pans. Crop yields and available moisture data are compared with fallow and continuous cropping of unleveled dryland areas.

PROCEDURE

The relative flat plains of eastern Colorado are dissected by broad natural waterways which provide good drainage to well defined intermittent streams. The waterways vary in width from 500 to 1000 feet with slopes of nearly level to about three percent. Within a waterway on the experiment station near Akron, Colorado, a series of five level pans were constructed beginning in 1958. The size of pans were limited by the width and slope of the natural channel. Individual pans varied from 2.5 to 6.6 acres in size with their respective contributing watersheds varying from 18 to 360 acres. The ratios are summarized in Table 1.

Pans were constructed with track and/or wheel type tractor and scraper. Approximately 7800 yards of soil were moved. Maximum cuts of 1.0 to 2.2 feet were made; however, the areas subjected to these excessive cuts were less than five percent of the total. Pans were leveled to zero grade and smoothed with a land plane.

Runoff measuring flumes equipped with FW-1 waterstage recorders were installed at upper and lower ends of each pan to measure inflow and outflow. Dikes were constructed around each pan to divert runoff through the flume from outside areas. A 6-inch plank was installed above each outflow flume to impound six inches of water in the pan. Runoff in excess of this depth overflows through a flume on to a pan at a lower elevation. Planks may be removed to drain the pan if moisture is excess to crop needs. Any depth of water can be impounded by varying the width of the plank.

Nitrogen in the form of ammonium nitrate (33.5 percent nitorgen) was applied annually in the pans at a rate of 50 pounds per acre of all crops. The check areas were not fertilized. Unpublished research results at Akron have indicated that crops do not respond to nitrogen in hardland soils under dryland conditions. Studies have been initiated to verify crop response to nitrogen on unleveled areas.

Soil moisture was assessed to depth of five feet at seeding and harvest times. Rainfall data were collected from a recording raingauge which was centrally located among all level pans.

Of the crops grown in individual pans, grain and forage sorghum were the only crops which have been tested for five or more consecutive years. Results reported herein are for years 1962 through 1964 in which flumes were installed to measure actual quantities of runoff.

RESULTS

Annual precipitation and runoff at the experiment station are summarized by months in Table 2. Average annual precipitation for 1962 through 1964 was 1.76 inches below the 57-year mean of 16.65 inches. Approximately 80 percent of the total precipitation occurred in April through August. Rainfall during this period usually originate from convective type storms of short duration and high intensity.

Long term annual runoff for this location is not known. An estimate of average annual runoff for the Akron area was made by utilizing annual runoff data from a number of experimental watersheds in the Great Plains of Nebraska, Kansas, Colorado, Oklahoma, and Texas (6). The relationship between calendar year precipitation and annual surface runoff from these locations is shown in Figure 1. From this relationship the annual runoff for the Akron, Colorado area would approximate 0.9 inch in normal rainfall years.

Average annual runoff at the experiment station near Akron, Colorado during 1962 through 1964 was 0.43 inch. Runoff was measured from 23 watersheds varying in size from 1/4-acre to 357 acres. All runoff occurred from May through October. None was observed from snow melt which is evident only in some years. Less than 5 percent annual runoff is expected to be lost in snow melt runoff.

Available soil moisture at seeding time is summarized in Tables 3 and 4 for grain and forage sorghum, respectively. The pans stored as much moisture in 7 months over winter as fallow over a 19-month period. This increase in storage efficiency was due to the pans retaining all precipitation and runoff, whereas some moisture was lost in runoff from unleveled fallow areas. Quantity of moisture stored in these areas was effected by the amount of crop residue and its ability to trap blowing snow during the winter. In unleveled areas after annual cropping, available moisture at seeding time was 2.3 to 3.7 inches less than moisture stored in the pans over a comparable period of time. Amount of moisture stored in any year depended on the amount of precipitation received during the storage period. In the spring of 1963, precipitation during the first five months was far below normal.

Distribution of stored moisture in a 5-foot profile is graphically presented in Figure 2 for leveled pans and unleveled fallow and check areas. Distribution and depth of moisture penetration in level pans at seeding time each year were nearly equal to that on fallowed areas after 19 months of storage. In unleveled areas after continuous cropping, moisture storage was nearly half of that stored in level pans with greatest differences occurring in the third through the fifth foot. Moisture stored in level pans and fallowed areas was 64 percent of field capacity by seeding time compared to 34 percent on annually cropped unlevel areas.

Rainfall and runoff received in level pans or lost from unleveled areas during the growing season is shown in Tables 3 and 4. In 1962 through 1964 average rainfall was about 2.2 and 1.5 inches below the long term mean for the growing seasons of forage and grain sorghum respectively. During the same period the pans received an extra four to six inches of moisture from impounded runoff. Annual moisture losses in runoff from unleveled areas was 0.7 to 0.8 inch.

Level pans increased total available moisture by about 9.0 inches over unlevel areas in continuous cropping and 5.0 inches over fallow. The difference in available moisture between level pans and unleveled fallow and continuous cropping was due to moisture received or lost in runoff.

Crop yields were significantly increased with increasing moisture supplies. The relationship is shown in Figure 3 for three years of data on grain and forage sorghum. Grain sorghum yields on the leveled pan averaged 2700 pounds per acre annually. This was a 56- and 89-percent increase over production after fallow and continuous cropping of unlevel areas, respectively. Fallowing increased yields 254 pounds per inch of moisture stored; yields from level pans were increased almost 280 pounds per inch of moisture received over fallow. Water-use efficiency increased with amount of available moisture.

Forage sorghum yields responded in like manner to more inches of available soil moisture. Oven-dry yields from the level pan were 2.8 times greater than from unlevel areas. Yields within the pan showed a decrease with increasing moisture supplies. This apparent relationship was due to a sorghum variety difference in 1963 and excessive moisture at seeding time in 1964 followed by drought later in the season. The average rate of increase between annual cropping of unleveled areas and level pan was 560 pounds of forage per inch of moisture received.

DISCUSSION

Pan leveling in broad natural waterways increased available moisture by retaining and storing the rainfall and runoff diverted from watersheds. The results were significant in years of below normal precipitation.

Increased yields in level pans were obtained each year as a result of increased moisture supplies, however, the magnitude of increase depended on timely distribution of rainfall. In 1963 most of the runoff producing rains were received during the period of maximum water-use by the crops which resulted in highest yields produced in the pans. In 1964 excessive moisture at seeding time made seedbed preparation difficult and delayed planting time a few days; where crop was planted, severe crusting occurred, causing non-uniform emergence and survival.

Pans were flooded once or twice each year. The impounded runoff usually infiltrated into the soil within a period of 36 to 48 hours. Approximately 90 percent of the annual runoff into the pans occurred in one or two intense rains. Runoff from less intense storms usually did not flood the entire pans.

Leveling precision for uniform moisture distribution in the pans should be as good or better than that required for irrigation leveling. In pans of considerable length it would be desirable to level at uniform grade of 0.5 to 1.0 percent to enhance water movement to lower ends. It is possible to utilize irrigation techniques for distributing water over the spreading area.

Nutrient deficiencies were observed in crop growth on exposed subsoils in the pans during the first two years. However, with annual application of nitrogen fertilizer the deficiencies were replenished to near the original fertility level. Some effects are still apparent on the excessive cut areas, but the deficiency is believed to be one of minor elements, such as iron or zinc.

The soil on sites where leveling is anticipated should be examined to determine depth and storage potential. Deep medium to moderately fine textured soils over moderately permeable subsoils are desired. Shallow or coarse soils should be avoided because of their low water-holding capacities. Soils in this experimental area were Goshen, Sligo, Rago, Weld, and Platner loams and silt loams. These soils are friable when moist, relatively deep, near the center of the waterways and have good water-holding capacities (4). They constitute most of the higher productive soils in this area and lend themselves to greater diversification of crops when water is available.

Available water-holding capacity of soils in the pan approximate 12 inches in 5 feet. Impounded runoff from most storms would probably be stored to this depth without seepage losses. Investigations are underway to check for water losses to deep seepage following the more intense storms.

Runoff was sometimes heavily laden with sediments but deposition within the pans has not been a serious problem. Runoff approaches most pans through grassed waterways at non-erosive velocities. Surface treatment of the contributing area would be a factor in the amount of sediments carried in runoff. Where surplus runoff was drained between immediately adjacent pans, drop structures were necessary to prevent erosion in the pan.

An optimum ratio of watershed to level pan area would be difficult to assess under existant conditions. Individual watersheds vary considerably in length and degree of slope and crop cover. For watersheds of varying characteristics tentative ratios of 25 to 1 might be considered optimum.

Dikes at lower end of pans are necessary to retain and spread in the pan. Dikes should have at least 12 inches settled height with 5 to 1 side slopes for easy maintainance and crossing of farm equipment. Spillways within the dike should be installed for controlled disposal of surplus runoff from the pan with provisions made for complete drainage if need arises.

Pan leveling by contractor cost $90 to $100 per acre which would include dike construction at lower ends. Costs would depend on size and shape of area and distance of haul. The increased gross return on grain or forage sorghum production was $30 to $40 per acre annually. In years of normal rainfall the increased return could offset the cost of pan construction in 3 to 4 years.

The level pans were large enough to utilize ordinary farm equipment for all cultural operations. Approximately five percent of the land in this area is suitable for level pan construction. The inclusion of such a spreader system in an overall farm program in dryland areas will give some insurance against complete crop failures in most years and may allow annual growth of crops which are not normally grown in the area.

SUMMARY

Level pans constructed in broad natural waterways increased moisture supplies by intercepting and storing the runoff that normally flows through them. Pans have conserved and utilized the moisture more efficiently than fallow or annual cropping of unlevel areas. The additional moisture stored in the pans has been sufficient to permit annual cropping with increased yields. Return on the investment would be great enough to offset costs in 3 to 4 years of normal precipitation.

References

1. Burnett, Earl, and Fisher, C. E. Land leveling increases dryland cotton production. Progress Report 1914, Texas Agr. Exp. Sta. December 19, 1956.
2. Dickson, R. E., Langley, B. C., and Fisher, C. E. Water and soil conservation experiments at Spur, Texas. Texas Agr. Exp. Sta. Bul. 587, 67 pp., 1940.
3. Hauser, V. I. and Cox, M. B. Evaluation of Zingg conservation bench terraces. Agricultural Engineering, 43 (8): 462-464, 467. August 1962.
4. Knobel, E. W. and others. Soil survey of Akron area, Colorado. USDA Series 1938, No. 14. November, 1947.
5. Colorado Engineering handbook for work and unit staff. Soil Conservation Service, USDA. Denver, Colorado.
6. Monthly precipitation and runoff from small agricultural watersheds in the United States, Agricultural Research Service, USDA. Beltsville, Maryland. 1957.

Table 1 - Acreage inventory of contributing watershed and pan areas in the waterspreading system.

Pan no.	Pan size acres	Watershed size acres	Ratio
1	6.4	357.3	56/1
2	6.6	18.4	3/1
3	3.0	138.3	46/1
4	2.5	63.5	26/1
1/ 5	2.8	- - -	- - -
Total	21.3	577.5	27/1

1/ Pan 5 has no contributing watershed, but receives excess runoff from pans 3 and 4.

Table 2 - Average precipitation and runoff by months for periods 1908-1964 and 1962-1964, inclusive, at the Central Great Plains Field Station, Akron, Colorado.

Month	Precipitation 1908-1964 inches	1/ Estimated long-term runoff inches	Precipitation 1962-1964 inches	2/Runoff 1962-1964 inches
January	0.32	.01	0.28	0.00
February	0.36	.02	0.26	0.00
March	0.77	.04	0.51	0.00
April	1.82	.10	1.14	0.00
May	2.89	.16	2.69	0.02
June	2.44	.14	3.71	0.24
July	2.64	.15	2.09	0.07
August	2.10	.12	2.07	0.06
September	1.37	.08	1.28	0.03
October	0.95	.05	0.39	0.01
November	0.53	.02	0.27	0.00
December	0.46	.02	0.20	0.00
Total	16.65	0.91	14.89	0.43

1/ Estimated volumes of runoff for Akron based on annual runoff from other locations in the western Great Plains area (6).

2/ Measured volumes of runoff from watersheds at Akron during the past 3 years.

Table 3 - Available growing season moisture, grain sorghum yields and water-use efficiency from Pan 1 receiving runoff and unlevel areas receiving no runoff for years 1962 through 1964.

	1/ Initial available soil moisture	2/ Growing season rainfall	3/ Runoff received or lost	Total Available moisture	4/ Grain sorghum yield	Water-use efficiency
Year	Inches	Inches	Inches	Inches	Lbs./A.	Lbs./inch
Sorghum after sorghum on level pan which received runoff.						
1962	8.76	6.94	2.09	17.79	2454	163
1963	5.48	12.39	6.08	23.95	4051	228
1964	9.06	6.29	4.79	20.14	1609	101
Mean	7.77	8.54	4.32	20.63	2705	166
Sorghum after fallow on unlevel areas with runoff losses						
1962	8.50	6.94	-0.41	15.03	1400	95
1963	6.73	12.39	-0.77	18.35	1372	84
1964	7.15	6.29	-1.14	12.30	773	78
Mean	7.46	8.54	-0.77	15.23	1182	86
Sorghum after sorghum on unlevel area with runoff losses.						
1962	4.56	6.94	-0.41	11.09	3.58	33
1963	2.71	12.39	-0.77	14.33	2.97	23
1964	4.79	6.29	-1.14	9.94	3.70	43
Mean	4.02	8.54	-0.77	11.79	3.08	28

1/ Available soil moisture to depth of 5 feet at seeding time.

2/ Growing season for grain sorghum was from 6-11 to 10-28.

3/ Runoff lost from unlevel areas was assumed to be the same as that measured from sorghum on similar slopes in another experimental area.

4/ Grain sorghum yields were determined at a moisture content of 12.5 percent.

Table 4 - Available growing season moisture, forage sorghum yields and water-use efficiency from Pan 4 receiving runoff and unlevel areas receiving no runoff for years 1962 through 1964.

Year	1/ Initial available soil moisture Inches	2/ Growing season rainfall Inches	3/ Runoff received or lost Inches	Total available moisture Inches	4/ Forage sorghum yields Lbs./A.	Water-use efficiency Lbs./Inch
	Sorghum after sorghum on level pan which received runoff.					
1962	7.53	6.15	2.61	16.29	12756	934
1963	5.81	8.46	6.21	20.48	6350	417
1964	8.79	4.12	9.76	22.67	4860	259
Mean	7.38	6.24	6.19	19.81	7989	503
	Sorghum after sorghum on unlevel areas with runoff losses.					
1962	6.63	6.15	-0.40	12.38	5162	477
1963	2.80	8.46	-0.74	10.52	1486	155
1964	5.84	4.12	-0.96	9.00	1922	282
Mean	5.10	6.24	-0.70	10.64	2857	315

1/ Available soil moisture to depth of 5 feet at seeding time.

2/ Growing season for forage sorghum was from 6-14 to 9-7.

3/ Runoff lost from unlevel check was assumed to be the same as that measured from sorghum on similar slopes in another experimental area.

4/ Forage sorghum yields are reported as oven-dry matter.

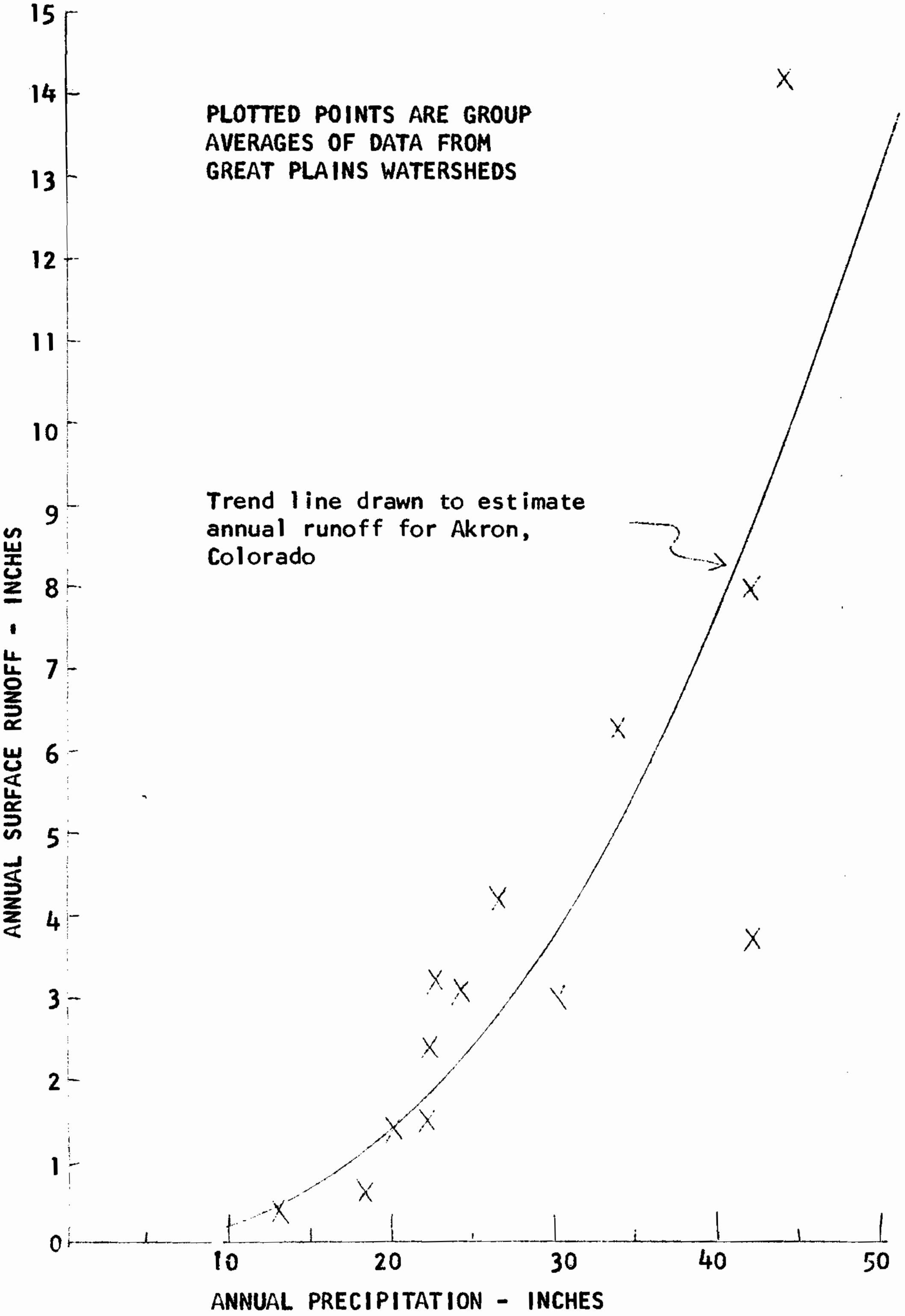

Figure 1 - Relationship between calendar year precipitation and annual surface runoff in the Great Plains area.

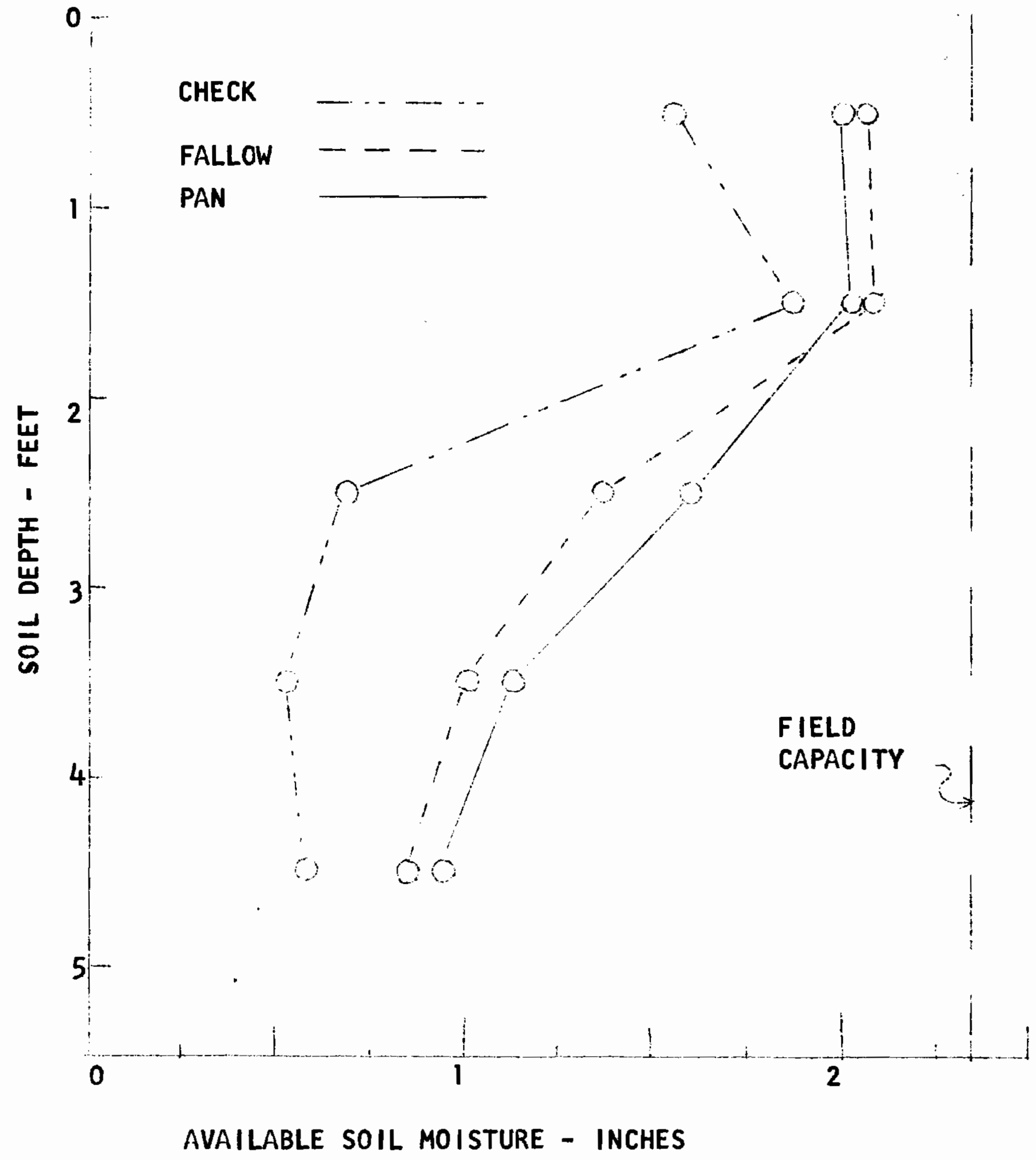

Figure 2 - Available soil moisture distribution to a depth of 5 feet at seeding time in level pans receiving runoff, in unlevel areas after 19 months of fallow, and in unlevel areas of continuous cropping.

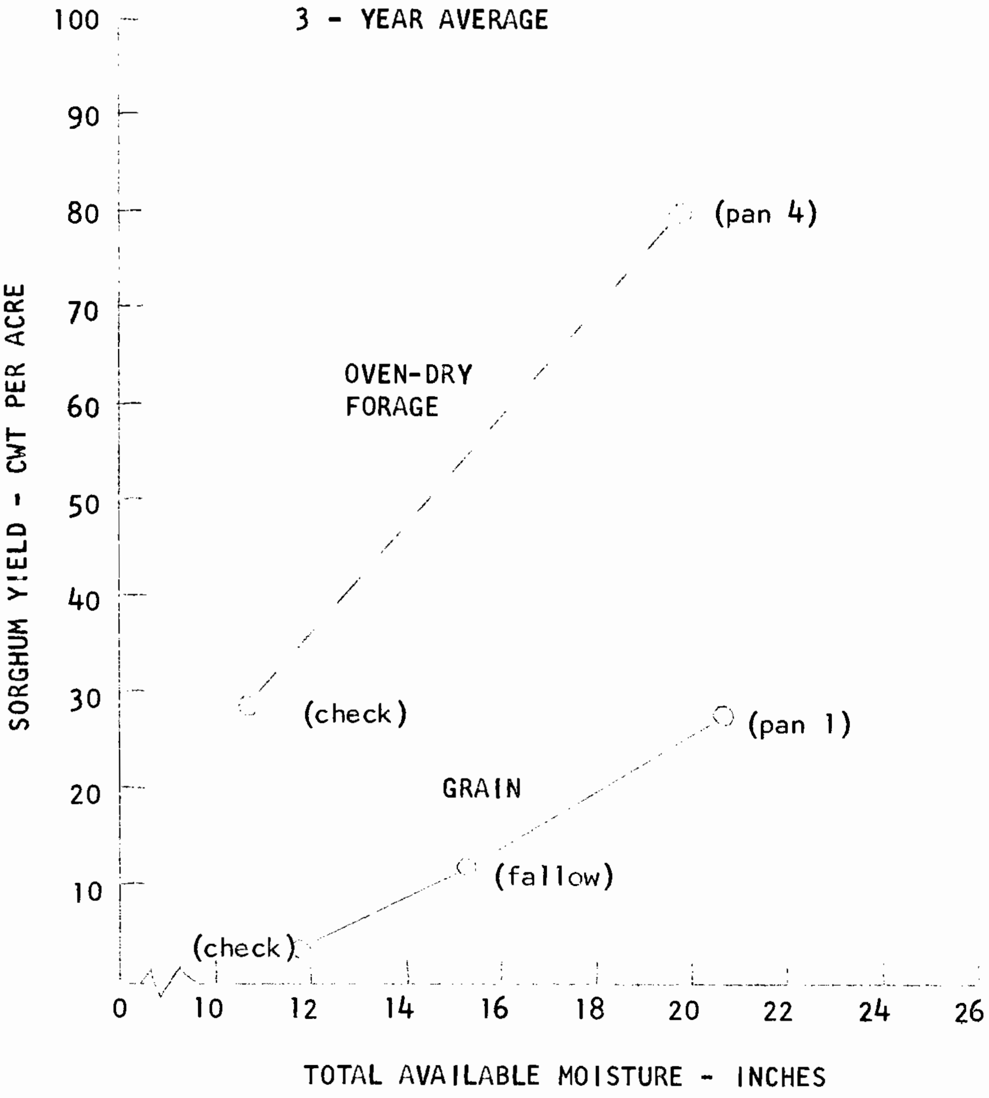

Figure 3 - Relationship between yields and total available moisture (initial soil moisture and growing season rainfall and runoff) for forage and grain sorghum grown in level pans, unlevel areas after 19 months of fallow and check (continuous cropping).